EXPERIMENTAL FISH GUIDANCE DEVICES

Position Statement of
National Marine Fisheries Service
Northwest Region
November 1994

National Marine Fisheries Service Northwest Region Position Paper on Experimental Technology for Managing Downstream Salmonid Passage

Summary

NMFS believes that positive-exclusion barrier screens, as described below, are appropriate for utilization in the protection of downstream migrant salmon at all intakes. However, the process described herein delineates an approach whereby experimental behavioral guidance devices can be evaluated and (if comparable performance is confirmed to the satisfaction of NMFS) installed in lieu of screens.

INTRODUCTION

Numerous stocks of salmon and steelhead trout in Pacific Northwest streams are at low levels and many stocks continue to decline. Idaho sockeye salmon and Snake River spring, summer, and fall chinook are listed as "endangered" under the Endangered Species Act. Petitions for additional listings are pending. It is essential to provide maximum protection for all salmonid juveniles to halt and reverse overall population declines.

The death and injury of juvenile fish at water diversion intakes have long been identified as a major source of fish mortality [Spencer 1928, Hatton 1939, Hallock and Woert 1959, Hallock 1987]. Fish diverted into power turbines incur up to 40 percent immediate mortality, while also experiencing injury, disorientation and delay of migration that may increase predation related losses [Bell, 1991]. Fish entrained into agricultural and municipal water diversions experience 100 percent mortality. Diversion mortality is the major cause of decline in some fish populations. For the purposes of this document, diversion loses includes turbine, irrigation, municipal, and all other potential fish losses related to the use of water by man.

Positive-exclusion barrier screens which screen the entire diversion flow have long been used to prevent or reduce entrainment of juvenile fish for diversions of up to 3000 cfs. In recent decades, design improvements have been implemented to increase the biological effectiveness of positive-exclusion screen and bypass systems by taking advantage of known behavioral responses to hydraulic conditions. Recent evaluations have consistently demonstrated high success rates (typically greater than 98 percent) at moving juvenile salmonids past intakes with a minimum of delay, loss, or injury.

(For diversion flows over 3000 cfs, such as at Columbia River main-stem turbine intakes, submerged traveling screens or bar screens are commonly used. These are not considered positive-exclusion screens in the context of this position statement.)

The past few decades have also seen considerable effort in developing "startle" systems to elicit a taxis (response) by fish, with an ultimate goal of reducing entrainment. This paper addresses research performed to avoid losses at intakes and presents a position statement for reviewing and implementing future fish protection measures.

JUVENILES AT INTAKES

Entrainment, impingement, and delay/predation are the primary contributors to the mortality of juvenile migrating salmonids. Entrainment occurs when fish are drawn into the diversion canal or turbine intake. Impingement occurs when a fish is not able to avoid contact with a screen surface, trashrack, or debris at the intake. This can cause bruising, descaling and other injuries. Impingement, if prolonged, repeated or occurring at high velocities also causes direct mortality. Predation (which is the leading cause of mortality at some diversion sites) occurs when fish are preyed upon by aquatic or avian animals. Delay at intakes increases predation by stressing or disorienting fish and/or by providing habitat for predators.

A. Positive-Exclusion Screen and Bypass Systems (PESBS)

Design criteria for PESBS have been developed, tested, and proven to minimize adverse impacts to fish at diversion sites. Screens with small openings and fish-tight seals are positioned at a slight angle to flow. This orientation allows fish to be guided to safety at the downstream end of the screen, while they resist being impinged on the screen face. These screens are very effective at preventing entrainment [Pearce and Lee 1991]. Carefully designed bypass systems minimize fish exposure to screens and provide hydraulic conditions that safely return fish to the river, thereby preventing impingement [Rainey 1985]. The PESBS are designed to minimize entrainment, impingement, and delay/predation from the point of diversion through the facility to the bypass outfall.

PESBS have been installed and evaluated at numerous facilities [Abernathy et al 1989, 1990, Rainey, 1990, Johnson, 1988]. A variety of screen types (e.g. fixed-vertical, drum, fixed-inclined) and screen materials (e.g. woven cloth [mesh], perforated plate, profile wire) have proven effective, when used in the context of a satisfactory design for the specific site. Facilities designed to previously referenced criteria consistently resulted in a guidance efficiencies of over 98 percent [Hosey, 1990, Neitzel, 1985, 1986, 1990 a,b,c,d, Neitzel, 1991].

The main detriment of PESBS is cost. At diversions of several hundred cubic feet per second and greater, the low velocity requirement and structure complexity can drive the cost of fish passage to over $1 million. At the headworks, the need to clean the screen, remove trash, control sediment, and provide regular maintenance (e.g. seasonal installation, replacing seals, etc.) also increases costs.

B. Behavioral Devices

Due to the high costs of PESBS, there has been considerable effort since 1960 to develop less expensive behavioral devices as a substitute for positive fish protection [EPRI, 1986]. A behavioral device, as opposed to a conventional screen, requires a volitional taxis on the part of the fish to avoid entrainment. Some devices were investigated with the hope of attracting fish to a desired area while others were designed to repel fish. Most studies focused on soliciting a behavior response, usually noticeable agitation, from the fish.

Investigations of prototype startle-response devices document that fish guidance efficiencies are consistently much lower than for conventional screens. Experiments show that there may be a large behavioral variation between individual fish of the same size and species to startle responses. Therefore, it cannot be predicted that a fish will always move toward or away from that stimuli. Until shown conclusively in laboratory studies, it should not be assumed that fish can discern where a signal is coming from and what constitutes the clear path to safety.

If juvenile fish respond to a behavioral device, limited size and swimming ability may preclude small fish from avoiding entrainment (even if they have the understanding of where to go and have the desire to get there). Another concern is repeated exposure; fish may no longer react to a signal after an acclimation period. In addition to vagaries in the response of an individual fish, behavior variations due to species, life stage, and water quality conditions can be expected.

Another observation is that past field tests of behavioral devices have been deployed without consideration of how controlled ambient hydraulic conditions (i.e. the use of a training wall to create uniform flow conditions, while minimizing stagnant zones or eddies that can increase exposure to predation) can optimize fish guidance and safe passage away from the intake. Failure to consider that hydraulic conditions can play a big role in guiding fish away from the intake is either the result of the desire to minimize costs or the assumption that behavioral devices can overcome the tendency for poor guidance associated with marginal hydraulic conditions. The provision of satisfactory hydraulic conditions is a key element of PESBS designs.

The primary motivation for selection of behavioral devices relates to cost. However, much of the cost in PESBS is related to construction of physical structures to provide hydraulic conditions which are known to optimize fish guidance. Paradoxically, complementing the behavioral device with hydraulic control structures needed to optimize juvenile passage will compromise much of the cost advantage relative to PESBS.

Skepticism about behavioral devices, at this stage of their development, is supported by the fact that few are currently being used in the field and those that have been installed and evaluated seldom show consistent guidance efficiencies over 60 percent [Vogel, 1988, EPRI, 1986]. The louver system is an example of a behavioral device with a poor record. Entrainment rates were high, even with favorable hydraulic conditions, due to the presence of smaller fish [Vogel, 1988, Cramer, 1973, Bates, 1961]. Due to their poor performance, most of these systems were eventually replaced by PESBS.

EXPERIMENTATION PROCESS

However, there is potential for future development of new and acceptable screening and behavioral guidance devices that will safely pass fish at a rate comparable with PESBS. These new concepts are considered "experimental" until they have been through the process described herein and have been proven in a prototype evaluation validated by National Marine Fisheries Service (NMFS). These prototype evaluations should occur over the foreseeable range of adverse hydraulic and water quality conditions (i.e. temperature, dissolved oxygen). NMFS will not discourage research and development on experimental fish protection devices, but the following elements should be addressed during the process of developing experimental juvenile passage protection concepts:

(1)Consider earlier research. A thorough review of similar methods used in the past should be performed. Reasons for substandard performances should be clearly identified.

(2)Study plan. A study plan should be developed and presented to NMFS for review and concurrence. It is essential that tests occur over a full range of possible hydraulic, biological, and ecological conditions that the device is expected to experience. Failure to receive study plan endorsement from NMFS may result in disputable results and conclusions.

(3)Laboratory research. Laboratory experiments under controlled conditions should be developed using species, size, and life stages intended to be protected. For behavioral devices, special attention must be directed at providing favorable hydraulic conditions and demonstrating that the device clearly induces the planned behavioral response. Studies should be repeated with the same test fish to examine any acclimation to the guidance device.

(4)Prototype units. Once laboratory tests show high potential to equal or exceed success rates of state-of-the-art screening, it is appropriate to further examine the new device as a prototype under real field conditions. Field sites must be appropriate to (a) demonstrate performance at all expected operational and natural variables, (b) evaluate the species, or an acceptable surrogate, that would be exposed to the device under full operation, and (c) avoid unacceptable risk to depressed or listed stocks at the prototype locations.

(5)Study results. Results of both laboratory tests and field prototype evaluations must demonstrate a level of performance equal to or exceeding that of PESBS before NMFS will support permanent installations.

Conclusions

During the course of the past few decades, we have seen an increase in the number of unscreened stream diversions, and this trend is likely to continue unless corrective measures are implemented. Concurrently, anadromous fish numbers have dwindled. Proven fish passage and protection facilities, which have demonstrated high guidance rates at other sites, can provide successful passage at most diversion intakes.

Periodically, major initiatives have been advanced to examine the feasibility of experimental guidance systems. Results were generally poor or inconclusive, with low guidance efficiencies attributable to the particular device used. Often results were based on a small sample size, or varied with operational conditions. In addition, unforeseen operational and maintenance problems (and safety hazards) were sometimes a byproduct.

Nevertheless, some of these experiments show potential. To further advance fish protection technology, NMFS will not oppose tests that proceed in accordance with the tiered process outlined above. To ensure no further detriment to any fish resource, including delays in implementation of acceptable passage facilities, experimental field testing should occur simultaneous to design and development of a PESBS for that site. This conventional system should be scheduled for installation in a reasonable time frame, independent of the experimental efforts. In this manner, if the experimental guidance system once again does not prove to be as effective as a PESBS, a proven screen and bypass system can be implemented without additional delay and detriment to the resource.

Adopted

Original signed by Will Stelle 1/6/95

William Stelle, Jr., Date________
Regional Director

References

Abernathy, C.S., D.A. Neitzel, and E.W. Lusty. 1989. Velocity Measurements at Six Fish Screening Facilities in the Yakima Basin, Washington, Summer 1988. Annual report to the Bonneville Power Administration.

Abernathy, C.S., D.D. Neitzel, and E.W. Lusty. 1990. Velocity Measurements at Three Fish Screening Facilities in the Yakima River Basin, Summer 1989. U.S. Department of Energy Bonneville Power Administration Division of Fish and Wildlife.

Bates, D.W. and S.G. Jewett, Jr. 1961. Louver Efficiency in Deflecting Downstream Migrant Steelhead Transaction of the American Fisheries Society, Vol. 90., No. 3, p. 336-337.

Bell, Milo C., 1991. "Revised Compendium on the Success of Passage of Small Fish Through Turbines." Report for U.S. Army Corps of Engineers, North Pacific Division, Contract No. DACW-57-88-C-0070. Portland, OR.

Cramer, D.P. 1982. Evaluation of Downstream Migrant Bypass System - T.W. Sullivan Plant, Willamette Falls (Progress Report for Fall 1981 and Spring 1982 dtd October 11, 1982) PGE.

EPRI (Electric Power Research Institute). 1986. Assessment of Downstream Migrant Fish Protection technologies for hydroelectric application. EPRI, Palo Alto, CA.

Hallock, R.J. 1977. A Description of the California Department of Fish and Game Management Program and Goals for the Sacramento River System Salmon Resource. California Fish and Game, Anadromous Fisheries Branch Administrative Report. 16 pp.

Hallock, R.J., and W.F. Van Woert. October 1959. A Survey of Anadromous Fish Losses in Irrigation Diversions from the Sacramento and San Joaquin Rivers. California Fish and Game. Vol. 45, No. 4, pp. 227-266.

Hatton, S. 1940. Progress Report on Central Valley Fish, 1939. California Fish and Game, 26(3) pp. 334-373.

Hosey and Associates and Fish Management Consultants. 1990. Evaluation of the Chandler, Columbia, Roza and Easton Screening Facilities. Completion Report for the Bureau of Reclamation.

Johnson, P.L. 1988. Hydraulic Design of Angled Drum Fish Screens. In: Proceedings of the Electric Power Research Institute Conference on Fish Protection at Steam and Hydro Plants, San Francisco, CA., Oct. 28-30, 1987. EPRI CS/EA/AP-5663-SR.

Neitzel, D.A., C.S. Abernathy, E.W. Lusty, and S.A. Prohammer. 1985. A Fisheries Evaluation of the Sunnyside Canal Fish Screening Facilities, Spring 1985. Annual Report to the Bonneville Power Administration.

Neitzel, D.A., C.S. Abernathy, and W.W. Lusty. 1986. A Fisheries Evaluation of the Richland and Toppenish/Satus Canal Fish Screening Facilities, Spring 1986. Annual Report to the Bonneville Power Administration.

Neitzel, D.A., T.J. Clune, and C.S. Abernathy. 1990a. Evaluation of Rotary Drum Screens Used to Project Juvenile Salmonids in the Yakima River Basin. In: Proceedings of the International Symposium on Fishways '90. Gifu, Japan.

Neitzel, D.A., C.S. Abernathy, and E.W. Lusty. 1990b. A Fisheries Evaluation of the Westside Ditch and Wapato Canal Fish Screening Facilities, Spring 1989. Annual Report to the Bonneville Power Administration.

Neitzel, D.A., C.S. Abernathy, and E.W. Lusty. 1990c. A Fisheries Evaluation of the Wapato, Sunnyside and Toppenish Creek Canal Fish Screening Facilities, Spring 1988.

Neitzel, D.A., C.S. Abernathy, and G.A. Martenson. 1990d. A Fisheries Evaluation of the Westside Ditch and Town Canal Fish Screening Facilities, Spring 1990. Annual Report to the Bonneville Power Administration.

Neitzel, D.A., C.S. Abernathy, and E.W. Lusty. 1991. Evaluating of Rotating Drum Screen Facilities in the Yakima River Basin, South-Central Washington State. In: Fisheries Bioengineering Symposium. American Fisheries Society Symposium 10. Bethesda, MD.

Pearce, R.O., and R.T. Lee. 1991. Some Design Considerations for Approach Velocities at Juvenile Salmonid Screening Facilities. In: Fisheries Bioengineering Symposium. American Fisheries Society Symposium 10. Bethesda, MD.

Rainey, W.S. 1990. Cylindrical Drum Screen Designs for Juvenile Fish Protection at Two Large Diversions. In: Proceedings of the International Symposium on Fishways '90 in Gifu. Gifu, Japan.

Rainey, W.S. 1985. Considerations in the Design of Juvenile Bypass Systems. In: F.W. Olson, R.G. White and R.H. Hamre, Proceedings of the Symposium on Small Hydropower and Fisheries, Aurora.

Skinner, J.E. 1974. A Functional Evaluation of a Large Louver Screen Installation and Fish Facilities Research on California Water Diversion Projects. In: Proceedings of the Second Workshop on Entrainment and Intake Screening. Johns Hopkins University, Baltimore, MD., February 5-9, 1973.

Spencer, John. 1928. Fish Screens in California Irrigation Ditches. California Fish and Game, Vol. 14, No. 3, p. 208-210.

Vogel, D.A., K.R. Marine and J.G. Smith. 1990 or 1988. A Summary of Upstream and Downstream Anadromous Salmonid Passage at Red Bluff Diversion Dam on the Sacramento River, California, U.S.A.. In: Proceedings of the International Symposium on Fishways '90 in Gifu. Gifu, Japan.